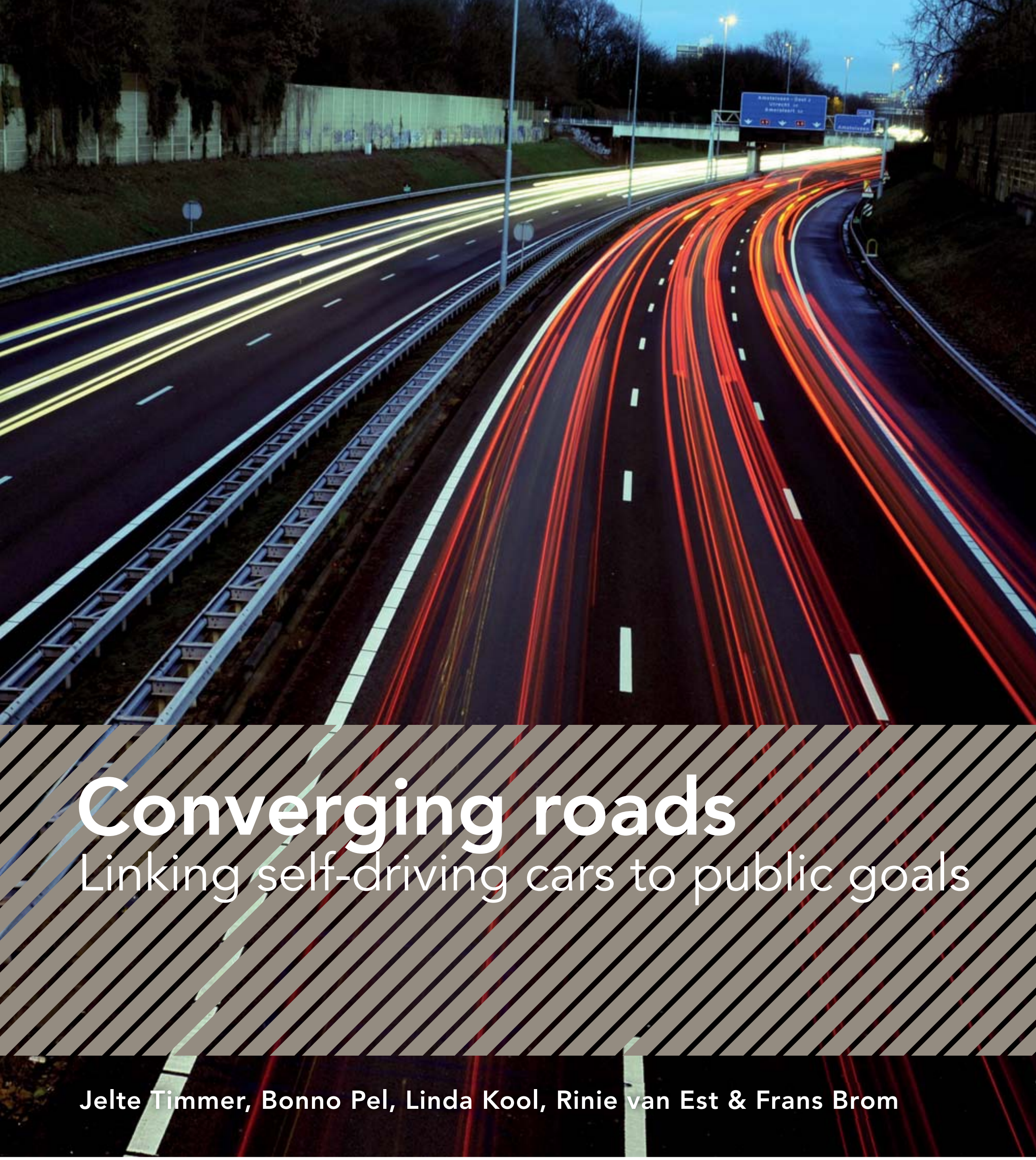

Converging roads

Linking self-driving cars to public goals

Jelte Timmer, Bonno Pel, Linda Kool, Rinie van Est & Frans Brom

Rathenau Instituut

The Rathenau Instituut promotes the formation of political and public opinion on science and technology. To this end, the institute studies the organization and development of science systems, publishes about social impact of new technologies, and organizes debates on issues and dilemmas in science and technology.

Converging roads

Linking self-driving cars to public goals

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Publisher: Rathenau Instituut
Translantion: Balance2
Illustrations: Jacob & Jacobus, Job de Vogel, Woerden
Lay-out: Boven de Bank, Zeist
Cover image: Hollandse Hoogte
Printing: Quantes, Rijswijk

This book is printed on FSC-certified paper.

First printed: February 2015

ISBN/EAN: 978-90-77364-65-9

Preferred citation:
Timmer J., B. Pel, L. Kool, R. van Est & F. Brom, Converging roads - Linking self-driving cars to public goals. The Hague, Rathenau Instituut 2015

Converging roads
Linking self-driving cars to public goals

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Foreword

Digitisation is set to change mobility drastically in the period ahead. With every TV-commercial I see, cars seem to be getting smarter and more self-driving. Car manufactures even predict to be able to introduce completely self-driving cars within ten to fifteen years. However, giving the dream of a self-driving car a closer look, there still is much that remains unclear. The mission of the Rathenau Instituut is to clarify these opportunities and challenges, and stimulate public debate on technological developments such as self-driving cars. In this report we present the results of a series of stakeholder interviews, literature review and a policy workshop, aimed to gain a better understanding of the development of self-driving cars in the context of Dutch and European mobility policy.

Over the past years, policymakers in the Netherlands focused on improving traffic management by creating so called cooperative systems: cars that connect and communicate with other cars and with roadside infrastructure. The Netherlands invested in these technologies to reduce congestion and create a safer, more environmentally friendly traffic system.

More recently however, autonomous robot cars, such as those developed by Google, have gained the interest of policymakers. This report shows that because of the technologies involved, the autonomous robot car contributes less to reducing congestion and environmental pollution. If the Netherlands wants to achieve its policy objectives the robot car should be embedded in a cooperative communication structure, for example by setting conditions for vehicle communication so robot cars can also be 'connected' cars.

Another emerging issue discussed in this report is the growing importance of data in mobility. The fact that the innovations in self-driving cars are powered by information technology results in an explosion of available data and a rise in possible applications enabled by that data. For example, car manufacturers can carry out maintenance by installing software updates via WiFi. And insurance companies conduct trials with track-and-trace modules that monitor your driving behaviour. But what about the ownership of all this data? If I buy a car, wouldn't that mean that I own the data I create while driving? And for what objectives can these data be used by others? Responsible innovation in this field demands clear policy aims, which can only be established with the participation of civil-society organisations and the public. I hope therefore, that this study contributes to a lively and informed debate on the future of the self-driving car and the use of mobility data.

Dr. ir. Melanie Peters
Director, Rathenau Instituut

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En route to the self-driving car

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1 Introduction

In the past few years, the long-envisaged self-driving car has come closer to reality. Prototypes are demonstrating the rapid advance of the technology involved and car manufacturers have announced that they may be bringing self-driving cars onto the market in the foreseeable future. The reason for pursuing this aim is not just to enable us to drive without our hands on the wheel. The self-driving car promises us a safer, more sustainable, and more efficient system of transport, one in which traffic accidents – most of which are the result of human error or carelessness – could be prevented. Traffic congestion and fuel consumption could be reduced if intelligent cars drive close behind one another in platoons. According to the Netherlands Institute for Transport Policy Analysis (KiM), the national costs of congestion, accidents, and environmental damage caused by traffic were between 19.9 and 20.9 billion euros in 2012 (Kennisinstituut voor Mobiliteitsbeleid, 2013). And according to Dresden University of Technology, the cost to the European Union of traffic accidents and environmental damage is estimated at 373 billion euros (Becker et al. 2012). Besides reducing these costs to society, developing the self-driving car can give a major economic boost to the mobility industry in both the Netherlands and the European Union.

It is therefore no wonder that the development of self-driving cars is on the agenda of policymakers. At European level, there are a number of EU-funded research projects to investigate the future of smart mobility, and treaties such as the United Nations Convention on Road Traffic are being amended to stimulate the development of (partly) self-driving vehicles (Miles & Graff 2014). In late 2013, the Dutch Minister of Infrastructure and the Environment, Melanie Schultz van Haegen, went for a demonstration trip in a self-driving car as part of the Dutch Automated Vehicle Initiative (DAVI). In June 2014, the Minister wrote to the Dutch House of Representatives to say that she will promote the development of such vehicles (Parliamentary Documents II, 2013/14, 31305, No. 210). She asserted that by allowing tests and through flexible legislation, the Netherlands could play a pioneering role in the development of the self-driving car.

The self-driving car is therefore on the horizon. But if we look more closely, we see that it is not clear just what this vehicle should be like. Will it be an autonomous robot car like the Google car, or a cooperative car that drives in platoons on the motorway? Just what kind of car are we talking about when we refer to the self-driving car? And how do the various developments in this field relate to one another?

Different innovations are taking place simultaneously, raising a variety of social, political and governance issues. In this study, the Rathenau Instituut aims to shed light on the technological developments concerning the self-driving car.

We use the context of the Dutch mobility system to clarify the various developments that are taking place. However, the description of the dynamics of these developments is relevant not only to the Dutch debate about the self-driving car; it also provides insights for European policy discussions on mobility. The study describes how actors work in different ways to achieve the goal of the self-driving car, and how the different ways relate to one another. We show how these developments are driven and influenced by advancing digitisation. Next, we discuss what the various technological developments mean for the policies and programmes that have been developed in the Netherlands and formulate policy recommendations. How can the Netherlands use the self-driving car in such a way that it can achieve its policy objectives of safer and more sustainable traffic and less congestion, and contribute to the country's innovativeness?

1.1 Reader's guide

This study is based on a background study describing the development of Dutch and international policy regarding self-driving mobility. That study appeared in Dutch as *Tem de robotauto* [Taming the Robot Car] and is available via the Rathenau Instituut (Timmer & Kool 2014). We present the main findings of that study here, and discuss the current political and policy issues regarding self-driving cars. In the present report, we refer in a number of places to the in-depth background study for a detailed discussion of the parties involved in the innovation process, and the development of their views and interests. Input for the study came from a series of interviews with experts in the Dutch mobility sector, a review of the relevant literature, and a workshop for policymakers and other relevant stakeholders in the governance process.

We will first discuss the various paths of technological development and the different approaches to self-driving vehicles that result from them (Section 2). Next, we discuss how these developments should be seen in the context of existing policy and established interests at Dutch, European, and international level (Section 3). This provides an understanding of the dynamics of the field and the possible future of the various development paths. In addition to these innovation dynamics, we describe how digitisation – which forms the basis for the self-driving car – introduces its own dynamics and raises its own issues (Section 4). We then discuss what this means for Dutch mobility policy (Section 5) and we formulate our conclusions and recommendations for how the various developments towards self-driving traffic should be managed (Section 6). Our recommendations and conclusions target mobility policy in the Netherlands, but the interwoven nature of Dutch and European mobility policy means that they can also provide interesting input for a European discussion of the self-driving car.

2 Innovation paths to the self-driving car

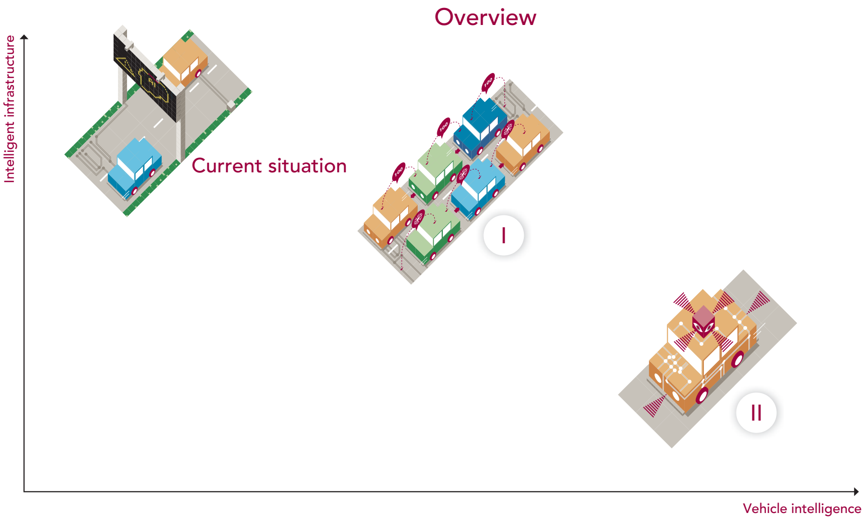
If we compare the various approaches to the self-driving car, we distinguish two dimensions. On the one hand, there is an approach that involves keeping the infrastructure as 'stupid' as possible, with all the intelligence incorporated into the vehicle, i.e. smart cars on stupid roads. At the other end of the spectrum, it is the car that is kept as stupid as possible, with the road being intelligent, i.e. stupid cars on smart roads. These two dimensions – the degree of intelligence in the infrastructure and the degree of intelligence in the car – are important to understand the different development paths for the self-driving car.

The Netherlands has a long tradition as regards smart roads. With loops in the road, matrix road signs and cameras, the country has been a pioneer in the field of traffic management. Following this innovation path of a smart infrastructure, there are many efforts in the Netherlands - and Europe - to investigate how smart cars and a smart infrastructure can be combined, thus creating a system of cooperative driving. This will enable cars to automatically drive in platoons on the motorway, with information on road conditions being transmitted between them and to traffic managers. The cooperating vehicles will be self-driving because they communicate both with roadside systems and with one another; the DAVI car mentioned in the introduction is an example of such self-driving, cooperative cars.

Besides this cooperative driving approach rooted in traffic management, there is another approach to the development of self-driving cars, based on the intelligence of the vehicles themselves. The Google car shows that by using sensor technology and smart algorithms, it is possible to develop self-driving vehicles that are not dependent on communication between the vehicles and the infrastructure. With cameras, GPS, radar, and support programmes, vehicles can autonomously 'read' their environment and on that basis take over driving tasks from the motorist. Because the car does not depend on cooperative communication systems, we refer to it in this study as the (autonomous) robot car. Both the robot car and the cooperative car take over driving tasks from the driver. In the case of the cooperative car, that process is gradual, with more and more systems being connected up so that an ever-increasing number of driving tasks can be automated. The aim with the robot car as developed by Google is to switch to completely automatic driving all at once.

This means that besides the current system of high-quality traffic management (smart roads and 'stupid' cars), we are dealing with two directions for future development: (I) the cooperative self-driving vehicle and (II) the autonomous robot car.[1] We describe here what these developments look like.

Figure 1 Development approaches: (I) cooperative systems and (II) robot cars



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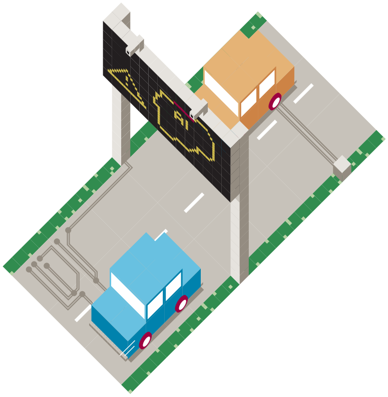
2.1 Advanced traffic management – current situation

The Netherlands has a long tradition in the field of traffic management. That tradition began with the introduction of traffic lights and static road signs, and has developed in recent decades into the current situation in which traffic flows are tracked with increasing accuracy by means of cameras, detection loops, and data from GPS systems and mobile phones. This information is used to direct the flow of traffic on the road network as efficiently as possible by means of information on matrix road signs, dynamic route information panels (DRIPs), and other information channels. Starting with the aim of reducing congestion through better road utilisation, Dutch traffic management has developed to a high level. That is not surprising given that the Netherlands is a densely populated country with a heavily used road network. The high standard of traffic management shows that even with relatively 'stupid' vehicles it is still possible to greatly improve traffic flow. For the Netherlands, traffic management is the starting point for the development of intelligent vehicles that can cooperate with the smart infrastructure.

1 For more information about the different approaches, see Section 9 ('Network of technologies') of the background study *Tem de robotauto* (Timmer & Kool, 2014).

Figure 2 An impression of advanced traffic management



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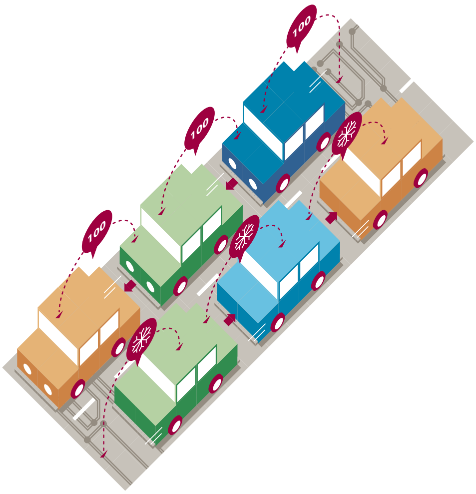
2.2 Cooperative systems – policy aims

Based on the existing system of traffic management in the Netherlands and Europe, steps are being taken towards cooperative systems in which network technology is used to connect intelligence in cars with an intelligent infrastructure – hence the term 'cooperative'. These networks will be used to provide cooperative cars with information about their environment. Based on that information, they can become highly automated and even made self-driving. But unlike the autonomous robot car, which is based on an autonomous detection system, the cooperative car depends first and foremost on a communication network.

One important distinctive advantage of cooperative systems is that they enable platooning. The cooperative cars can be linked to one another via the communication network so as to drive and brake at the same speed. Because they are in direct communication with one another and no account needs to be taken of human reaction time, they can drive very close to one another in the form of platoons. This reduces friction and as such enables efficient and more environmentally friendly driving and improves traffic flow. In this way, the cooperative car can contribute to several Dutch and European policy objectives: greater comfort and safety, environmental benefits, and less congestion. One significant challenge in developing cooperative systems is that the network needs to connect systems of different origin, which requires a common 'language' or communication standard(s). Without such agreements, the systems of different car manufacturers, road management authorities, and the traffic sector will be incompatible.

Figure 3 An impression of cooperative systems



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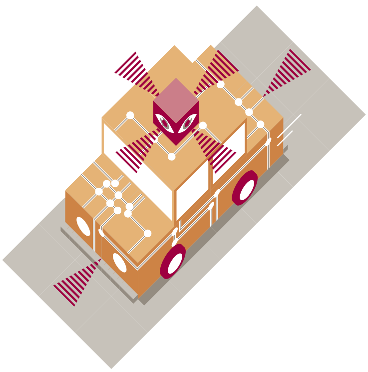
2.3 Self-driving robot cars – disruptive innovation

Finally, there is a third perspective in which the intelligence is incorporated into the car itself and no direct communication is basically required with the infrastructure or with other vehicles. Using intelligent sensors, radar technology and 3D cameras, the car creates an image of its surroundings by itself. This approach plays a major role in the United States, partly thanks to the pioneering role that Google has taken upon itself in California by developing the Google car. Because the car does not depend on cooperative communication systems, we refer to it in this study as the (autonomous) robot car.

Because the technology is situated in the car itself, car manufacturers or other parties, such as Google, can develop robot cars largely independently; they are only dependent to a limited extent on other parties and shared standards. The robot car does, however, require technology that is at present too expensive for commercial applications: perceiving the environment requires a combination of cameras, radar systems, a laser rangefinder and GPS, with the notable addition of the accurate digital maps that Google is developing with its camera cars (Google 2013; Guizzo 2011). Powerful processors and sophisticated software programs are also necessary in order to process the data flawlessly to generate steering information. The robot car therefore requires no communication with other vehicles or roads in order to operate, but without such communication, platooning is not possible. This is because robot cars cannot be linked to one another directly as regards their speed, direction, and braking. The safety margins that these sensor-driven systems require in order to react make it impossible for robot cars to drive close together. As a result, achieving policy goals such as environmental benefits and improved traffic flow are not obvious possibilities with autonomous robot cars.

The approach of developing (autonomous) robot cars is radically different to the cooperative approach. Google is producing prototypes of robot cars without a steering wheel or pedals and has stated that it aims to switch to fully automatic driving all at once. The prototypes are small cars with a top speed of 40 kph and designed for short trips in urban areas (Markoff 2014). Cooperative driving is based on more gradual development: self-driving capabilities are gradually added to connected cars, and will first be applied in driving on motorways only. For the Netherlands and Europe, the development track leading towards robot cars can be seen as a disruptive innovation because it presents a radically different method to that pursued by policymakers for many years now. This will be explained in greater detail in the following section.

Figure 4 An impression of the autonomous robot car



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3 Innovation dynamics

As we have seen in the previous section, self-driving vehicles develop, broadly speaking, along two different paths: (1) cooperative systems that build on advanced traffic management and (2) self-driving robot cars. Both these perspectives are developing within different fields of competitive forces and interests. The cooperative driving approach derives from EU and Dutch policy aims and strategies. Promoted by the prototypes and ambitions of Google, the approach involving autonomous robot cars is receiving a relatively large amount of attention in the United States.

3.1 Development of cooperative systems in the Netherlands and Europe

The background of the Netherlands in traffic management is important in order to understand the development of cooperative systems. Traffic management is indispensible if the heavily used Dutch road network is to function effectively. Traditionally, controlling and coordinating traffic flows has been a task of government, arising from policy goals such as combating congestion and promoting quality of life and sustainability. In the past few decades, however, traffic management has shifted from being primarily a public task to that of a public-private partnership. The course of this process in the Netherlands shows how establishing such public-private partnerships creates tensions and challenges as regards coordinating the cooperation.

In 1996, the policy memorandum on *Travel Information* [Reisinformatie] indicated that the government would focus on creating the right conditions for traffic management to be organised by the market, for instance through the provision of high quality information. Market parties were thus given the liberty to exploit traffic information and develop customer-focussed services. That liberalisation of traffic management demanded the coordination of private and public interests. Finding the right balance between those interests constituted a learning process. Based on their specific interests, road management authorities were concerned about what the liberalisation process would mean for the effectiveness of traffic management, while entrepreneurs deplored the unstable investment climate caused by shifting policies and conditions for the use of traffic information. The lessons drawn from this formed the background to development of the current policy agenda *Better Informed on the Road* [Beter geïnformeerd op weg] (I&M 2013). This programme focuses on the future development of traffic management towards cooperative mobility. An important aim of this agenda is to ensure clarity and stability in order to take advantage of public-private cooperation and to work efficiently towards the policy goals of improved traffic flow, safety, and sustainability. In the Netherlands, there has therefore been a shift in recent years from advanced traffic management to cooperative systems, in which the coordination of private and public interests has been consolidated.[2]

Coordinating private and public interests is even more important for the development of cooperative systems, as it demands close cooperation between government and private parties. Public authorities are key players as they control the road infrastructure, but for the development of vehicle intelligence they are highly dependent on the industries concerned. This means that there is a high need for coordination and agreements on matters such as standardised communication protocols. Network organisations such as AutomotiveNL, Nederland Innovatief Onderweg, and Connekt play an important role in coordinating the various activities in the field of standardisation, product development, field trials, and roll out. Much has been invested in recent years in developing a joint approach, but coordinating cooperation remains a point of concern. This issue also plays a role in the development of cooperative systems at European level.

European context

The policy focus on cooperative systems and need for a shared 'language' demand close international cooperation. Developments in the Netherlands are in many ways framed by European rules, approaches, and coordination platforms. These are important to create the right conditions for investment and to put standards in place so that cooperative systems can cooperate everywhere. To ensue coordination at European level, the Amsterdam Group has been set up, a cooperation platform consisting of public and private parties. Figure 5 indicates how the Amsterdam Group sees the development of cooperative systems. The figure makes clear that this development is a gradual process, one in which cooperative systems are cross-linked to one another until finally a cooperative self-driving car can be created, which also takes over driving tasks from the driver. This is in line with the Dutch policy agenda *Better Informed on the Road* [*Beter geïnformeerd op weg*] (BGOW), which foresees a gradual increase in 'connected' vehicles. It is only at a later stage that the prospect of partially automated and eventually fully self-driving vehicles enters the picture.

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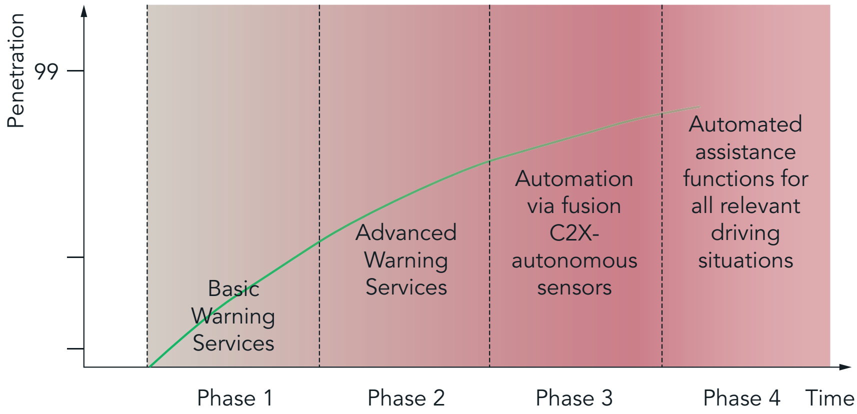
2 For more information about the development of traffic management towards cooperative systems in the Netherlands, see Section 11.1 'Nederland' of the background study *Tem de robotauto* (Timmer & Kool, 2014).

Figure 5 Phased development of cooperative systems according to the Amsterdam Group (2013)



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A major challenge in coordinating the development of cooperative systems is to avoid a situation in which both public investment in smart roads ('roadside systems') and private investment in vehicle systems lag behind because each party is waiting for the other to invest. Both parties will only see a return on their own investment if 'the other side' has also invested in the intended communication network. Because of this mutual dependence, there is a constant threat of the parties involved delaying investment and focusing on their respective core business of vehicle production or traffic management.

Ensuring the necessary coordination and making arrangements at international level is no easy matter. The global nature of the car industry means that regulation is organised at international level and that establishing rules is surrounded by conflicts of interest. Manufactures exert their influence through consultation and lobbying, and the participating Member States also keep a close eye on the interests of their national industry. The major European automobile-producing countries such as the UK, Germany, and France therefore have a great influence on agreements. Such dominant interests can lead to Dutch private and public interests coming under pressure. Those interests are not in the field of automobile production but above all in the automotive supply industry, the traffic sector, and the production of 'nomadic devices' such as external navigation systems. The development of cooperative systems therefore requires coordination of public and private interests at national and international level. Using the resulting systems, progress is gradually being made towards increasing automation of driving tasks, until finally the self-driving car comes into view. This approach consequently differs from the focus on the self-driving robot car, which is seen in the United States as a rapidly approaching reality.

3.2 Development of autonomous robot cars in the United States

The Google car has attracted a great deal of attention in the United States as an example of Silicon Valley's innovative character. Special legislation has been introduced in a number of states to allow self-driving vehicles to be tested on public roads. As a result of that legislation, prototypes of self-driving vehicles have now covered several hundred thousand kilometres without the intervention of a human driver. This has reduced the scepticism about self-driving vehicles, and it has endowed the market launch of a self-driving car with the appeal of a realistic future event. Instead of gradual networking with cooperative systems – thus laying the basis for automating driving tasks and ultimately a self-driving car – Google views a self-driving robot car specifically as the starting point, with cooperative vehicle communication being something that can be added later (Poczter & Jankovic 2013, 11).

The Google car is a good example of the idea of the self-driving robot car. The development of robot cars is driven mainly by private parties engaged in the full-scale development of vehicle intelligence. It should be noted, however, that American automobile manufacturers and Google itself differ as to how they see the development and introduction of self-driving vehicles. Where Google wishes to take driving entirely out of the hands of the driver, the manufacturers appear to prefer to expand vehicle intelligence step by step (Oreskovic & Klayman 2014). Despite these differences, it is characteristic of both parties that their focus is on vehicle intelligence. This focus on autonomous vehicle intelligence limits the level of dependence on other parties and allows the manufacturers to keep control of their product and its development. A number of American states have drawn up rules that allow the further development and testing of this vehicle intelligence in actual practice.[3] States are being encouraged to do this by industry lobbying and by the opportunity to promote themselves as innovative (Pritchard 2014).

It is relevant to note that there is in fact growing attention at federal level in the United States for organising vehicle communication. In February 2014, the federal government announced that it would be taking steps to regulate vehicle communication (NHTSA 2014). Drawing up and imposing the required standards is likely to prove a difficult hurdle. Automobile manufacturers are wary of mandatory technology, and previous experience of large-scale standardisation in the United States shows that this can be fraught with difficulty. The societal benefits of cooperative systems that play an important role in the Netherlands, for example improved traffic flow and sustainability, are of less significance in American political culture compared to the freedom of drivers and manufacturers (Gifford 2010).

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3 For a description of Google's sophisticated lobbying strategy regarding this legislation, see Section 11.3 of the background study *Tem de robotauto* (Timmer & Kool, 2014).

Compared to the Netherlands and Europe, there has been less investment in the United States in smart infrastructure, and traffic management plays a less important role. Against that background, the strong development of vehicle intelligence is understandable. The iconic Google car presents itself as a new disruptive innovation from Silicon Valley: a robot car that has no need of cooperative communication and that follows a development path in which the self-driving robot car is not merely a speck on the horizon but precisely the starting point. Nevertheless, development of the robot car in the United States is anchored in a context in which attention is being paid to the development of cooperative systems, as is shown by the regulations that have been announced in the field of vehicle communication (NHTSA 2014).

3.3 Moving to a shared playing field

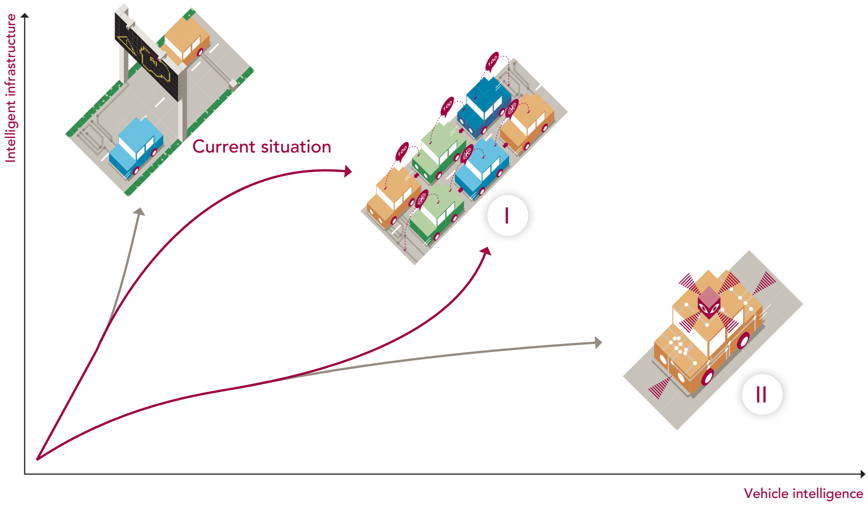
The Californian example of innovative technology and incentivising legislation is also attracting attention in the Netherlands and Europe. In the Netherlands, for example, the Minister's memorandum (June 2014) to the House of Representatives on tests with self-driving cars referred to the Californian legislation as an example of how the Netherlands could play a pioneering role in Europe (Parliamentary Documents II, 2013/14, 31305, No. 210). That memorandum emphasises the speed with which vehicle intelligence is advancing. Initiatives such as the DAVI demonstration car show that the self-driving car is not merely a prospect far off in the future. Besides the steady development of cooperative systems (as promoted by BGOW/Connecting Mobility), the development path leading towards autonomous robot cars is gaining attention in Dutch policymaking.

The private parties that are responsible for the development of autonomous robot vehicles in the United States see cooperative systems as a technology that can be added later. But both in America and Europe there is an increasing awareness that cooperative and autonomous systems will need to complement one another in order to create a viable self-driving car. Experts from both development perspectives recognise the importance of bringing the two approaches together in order to fully reap the benefits: convergence is necessary if the self-driving car is to be sufficiently reliable and cost-efficient[4] (see Figure 6). The US federal government has therefore placed regulation of vehicle communication on the agenda. The lower red arrow in Figure 6 shows the American approach, which focuses strongly on the development of autonomous robot cars. The upper red arrow shows the European approach, which aims to use cooperative systems to create a solid basis for the development of fully self-driving cars.

4 For more information about the need for convergence, see Section 11.4 of the background study *Tem de robotauto* (Timmer & Kool, 2014).

Nevertheless, the convergence envisaged by the policymakers may fail to materialise. As we have already seen, the necessary process of coordination and alignment is a complex one, and a lot of different interests are involved. Both vehicle manufacturers and road management authorities may choose to pursue their own course, for example because they believe that doing so will give them more control over their own innovation processes. If governments and road authorities develop traffic management further on the basis of separate investment strategies, the major boost in effectiveness provided by intelligent vehicle technology will fail to materialise. Moreover, if vehicle manufacturers bring relatively autonomous robot cars onto the market, the potential synergy with policy goals such as environmental benefits and improved traffic flow will be limited. The grey arrows in Figure 6 show these alternative approaches.

Figure 6 Convergence or divergence in development of the self-driving car



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3.4 Conclusion

With a view to the necessary convergence, the recent focus on the 'autonomous robot car' in Dutch policymaking – which focussed so strongly on traffic management and cooperative driving – can therefore be considered positive. However, in Dutch policy it is not sufficiently clear, that the two approaches – cooperative and autonomous – are fundamentally different, both technologically and with respect to what policy objectives can be achieved, for example improved traffic flow and environmental benefits.

This tension between convergence and divergence applies not only at the level of the Netherlands but just as much at European and global level. If the Netherlands and also Europe wish to take advantage of the disruptive innovation of the robot car, benefit from previous (public-private) investment and the opportunities for their own industry, and achieve multiple policy goals, then robot cars must be embedded in the cooperative communication structure. Conditions now need to be imposed for intelligent vehicle technology so that robot cars will also become 'connected' cars. This Dutch case shows that major benefits can be gained by combining the development of cooperative and autonomous vehicle systems.

4 Dynamics of digitisation

The previous section has shown that the development of the self-driving car is a complex process and that its outcome is uncertain. Cooperative systems and vehicle intelligence can be combined but convergence is not a given. Within this development, however, a dynamic can be distinguished that plays a central role in both innovation paths and that confronts us with new societal, political and governance issues, namely the increasing digitisation of mobility. Smart information technology is the driving force behind the various technological developments in both the car and the infrastructure. The more vehicles and infrastructure that are equipped with smart technology, the greater will be the explosive growth of data that they create, and the potential applications that can be built upon that data. There will consequently be a fundamental change in the role of data in mobility, with data becoming central to the functioning and organisation of mobility, representing significant value, and forming the basis for new revenue models. At the same time, it means that issues regarding privacy, data protection, re-use and ownership of data are of a different nature and demand attention. We will therefore look separately at the dynamics entailed in digitisation.

4.1 Big data and new revenue models

The data that cars equipped with smart vehicle technology collect about the way the vehicle is used can concern matters like: location, speed, braking and acceleration time, activation of safety systems, status of the engine and components, seat belt use, telephone and radio use, and the number of people in the car. The data can be used to monitor the performance of the car and to ensure better coordination of servicing. The car manufacturer Tesla, for example, even carries out maintenance by installing software updates via WiFi. Other applications are also possible, for example in the field of entertainment or marketing.

Car manufactures see the ‘car-to-cloud data pipeline’ as an extremely valuable source of future revenue (Diallo 2013). This is underscored by the activities of IT companies in the mobility field, for example Apple and Google. Both have released adaptations of their operating systems designed for smart vehicles, respectively called Apple CarPlay and Android Auto. As a control system in the car and as a platform for third-party apps, they are located in a central position in the network of the intelligent car. Data and data processing are expected to play a central role in their revenue models, as well as in the business model that Google will develop for its self-driving vehicle technology.

Other companies also foresee opportunities for new revenue models. The San Francisco-based company Kiip is working to bring a system on the market that sends personalised adverts to drivers based on data about their location and driving behaviour. One example might be an offer for an energy drink after the driver has covered 100 kilometres. The data generated by smart cars will also be of obvious commercial importance for insurers, as trials with a track-and-trace module that monitors driver behaviour show (Tuttle 2013).

The explosive growth in the volume of data and the value of that data are leading to discussion of the ownership of the data that a driver generates while driving. Currently, the purchase agreement for a car often stipulates that the purchaser will provide his data to the manufacturer.

> *"Any data which we collect or which you provide to us which is not identifiable to you, including functionality use, statistics, performance data, quality metrics, shall be owned by us" (Hyundai Blue Link privacy policy).*

Where previously it was perhaps taken for granted that the data that a manufacturer read out from the car's diagnostic system belonged to the manufacturer, that idea now seems to be changing. In the United States, the 'Your Car, Your Data' coalition aims to give drivers more control over the data that they generate with their car.

4.2 Big data and government objectives

Big data in the field of mobility also offers new possibilities for government. Firstly, location data from cars and navigation systems makes it possible to carry out traffic management in a more detailed and cost-efficient manner. Public and private data flows are intermingled here and are used in different ways by different parties. In the Netherlands, discussion is taking place about the handling of this data and how it can be made available. In line with Dutch policy, for example, efforts are being made to make this data available as open data so as to encourage innovation in traffic management, but account also needs to be taken of the interests of parties that have constructed a revenue model on the basis of collecting or processing this data. The National Data Warehouse for Traffic Information (NDW) therefore provides data not only 'open' and free of charge but also subject to licence and in return for payment, with there being a difference in the service level. At the same time, the possibilities are increasing for combining data and converting anonymous data (such as traffic data) into personal data. As a result, the principle of 'open data' is increasingly coming up against the legislation on privacy (Kulk & Van Loenen 2012).

Secondly, the data flows also offer possibilities for policy fields other than mobility. The Dutch Ministry of Security and Justice is considering how location data can be used for more effective law enforcement. The potential of data from smart vehicles for law enforcement is illustrated by a remark by Ford sales executive Jim Farley: 'We know everyone who breaks the law. We know when you're doing it. We have GPS in your car, so we know what you're doing.

By the way, we don't supply that data to anyone.' Farley later withdrew that remark, but it was repeated in various media and led to a great deal of discussion about what reuse of data should be permitted in the context of law enforcement.

Government also has the task of protecting the citizen's privacy. The possibilities provided by mobility data are leading to heated discussion of how the more extensive collection and exchange of data should take account of the privacy interests of the citizen. Those interests have already turned out to constitute a major obstacle to the introduction of variable road pricing in the Netherlands; the debate on that matter has shown that public acceptance of a technology solution is crucial (Griffioen 2011). In addition to the discussion on road pricing, there was a great deal of commotion in 2011 about the resale of anonymised data on driving speeds by navigation service provider TomTom. That data was sold to the police, which used it to determine where to position speed cameras. Although TomTom's action is legally permissible and the sale of anonymized data is covered in the terms and conditions for the use of navigation systems, the commotion shows that users did not agree with the way 'their' data was being reused.

5 Towards an innovation policy agenda

In the introduction, we asked what kind of car the self-driving car actually is. We have now seen that it can take various forms and is being developed according to various different approaches. Google's autonomous robot cars are attracting much attention, but they are being developed on different lines to the cooperative approach in the Netherlands and Europe. The market is pushing the development of vehicle intelligence, but for policymakers vehicle communication is interesting because, next to improving road safety, it also offers opportunities for sustainability and traffic management – important policy objectives in Netherlands and Europe.

The dynamics of developments regarding self-driving vehicles show that with the development of cooperative systems the Netherlands is adopting an approach that unites important policy objectives and economic interests. What do the insights in the dynamics of development of cooperative and autonomous cars mean for policy in the Netherlands? What measures are needed in order to foster the current development of cooperative systems and to achieve the country's policy objectives? What role should be assigned to the development of self-driving robot cars in Dutch policy? And how can we respond to new issues arising due to the increasing digitisation of mobility? We will describe the main features of an innovation policy agenda for the development towards self-driving vehicles. The lessons set out here focus on Dutch policy but they are also relevant to the European discussion about the self-driving car.

5.1 Investment conditions

Development of the cooperative self-driving car is dependent on private and public efforts. To avoid a situation in which both private and public parties delay investing until the other has taken action, then the right investment conditions must be created. This demands coordination and developing a joint approach. At both Dutch and European level, therefore, efforts are being made to align investment decisions. One important function of the Dutch *Better Informed on the Road* policy agenda is to set out clear conditions for investment, and the same applies to the Amsterdam Group's 'road map' for phased implementation (see Figure 5 on page 9). Shared research and testing facilities – for example the Dutch Integrated Test Site for Cooperative Mobility (DITCM) and the Dutch Automated Vehicle Initiative (DAVI) – generate important knowhow for the further development of smart mobility. These are important advances, but to achieve Dutch policy objectives more is necessary: a legal framework for liability is needed and the details need to be worked out of a fiscal framework to compensate for the costs and benefits of the self-driving car.

Framework for liability

Car manufacturers face major business risks due to product liability. This issue becomes increasingly complicated (and expensive) as onboard software becomes more complex and more after-sales products are installed in the car. Manufacturers risk being held liable for components developed by their suppliers. Therefore, many vehicle manufacturers try to keep their systems as 'closed' as possible, and are cautious about introducing systems that could improve safety (Van Wees 2010). Without new rules, these systems consequently remain 'on the shelf' for longer than is in fact technically necessary. Given that this issue is particularly relevant to vehicle technology, the responsive, market-stimulating regulatory frameworks in the various US states can offer instructive examples for the Netherlands. According to the NHTSA, the US federal highways safety watchdog, fundamental political choices need to be made between stimulating innovative entrepreneurship as opposed to guaranteeing road safety, and between the interests of car manufacturers and those of suppliers and the nomadic-device industry. In short, one important precondition is a clear, up-to-date, and well thought-out framework for the liability of various products and manufacturers.

Tax incentives

The cooperative car is expected to generate collective benefits such as road safety, reduced congestion and reduced emissions. Private parties cannot simply pass on the cost of those collective benefits in the price of their vehicles or services. A higher vehicle price will primarily be justified by direct consumer benefits such as safety and comfort. Governments can decide to use tax measures to encourage the development of the cooperative car because of the collective benefits.

The advent of the cooperative car also makes it necessary to consider other compensation models. Because smart vehicles can by definition be kept track of, it will be much easier to have payment made on a *pro rata* basis for services used. Variable road pricing is considered a political taboo in the Netherlands and is seen as a 'consumer-unfriendly' application. But various parties indicate that the necessary technology is already widely available, and that the Dutch supply industry is now recouping its investments in that technology elsewhere in the world. European standardisation of communication systems keeps open the option of such applications. The relevant leaders in this field are the United Kingdom, Sweden and Singapore, which have thus gained an international reputation for innovative and daring applications of Intelligent Transport Systems (ITS). The question arises for the Netherlands as to whether it also wishes to use the intelligent car as an intelligent billing system – a market condition that is (more or less) naturally included with this product.

5.2 Embedding and standardisation

The development of the cooperative car in the Netherlands raises the question of how to ensure that the robot car becomes embedded in the existing road system and infrastructure. The development of autonomous robot cars based on vehicle intelligence contrasts with the cooperative car, but we have already seen above that both experts and policymakers are aiming for convergence. Ensuring that these different developments can be combined requires international coordination and standardisation. Developing traffic management independently would be possible, but vehicle intelligence is being developed for international or even global markets, and standardisation is therefore also being adopted at international or global level. The issue of standardisation rightly has the attention of policymakers and politicians. Both the Dutch BGOW approach and the memorandum to the House of Representatives from the Minister of Infrastructure and the Environment (16 June 2014) regarding 'large-scale testing of self-driving cars' argue for an active approach in which government and market parties work together. It is important in this context for the Netherlands to maintain the focus on cooperative systems and to ensure that disruptive developments in vehicle intelligence, such as the Google car, are embedded in that approach to the maximum extent possible. This could entail regulation and requirements for vehicle communication which should also apply to intelligent vehicles. As we have seen, the federal government in the United States is now considering this.

Tension between international interests and those of the Netherlands

In the international arena, the Netherlands will need to be aware of its subordinate position relative to dominant countries with their own automotive industry. Such 'car-oriented' interests can lead to Dutch industrial and public interests coming under pressure. The industrial interests of the Netherlands mainly involve automotive suppliers, the traffic sector, and the nomadic-device industry. For the nomadic-device industry, it would be disadvantageous if, for example, the car industry were to impose technological requirements that would increase the cost price of nomadic devices.[5] Excessively vehicle-oriented standards may also be disadvantageous from the point of view of Dutch mobility policy. Motivated by congestion and environmental considerations, the Netherlands has already invested a relatively large amount in recent years in specially developed roadside systems to deal with these problems. Standardisation drawn up too much from the car manufacturer's perspective may result in roadside systems being sidestepped, and the potential for cost-effective and powerful mobility policy remaining underused.

The roadside systems have a lower rate of development than vehicle intelligence; nomadic devices in fact have a relatively faster product cycle. The Netherlands must therefore not allow itself to be led too much by the pace of the automotive industry but must press for European Intelligent Transport Systems (ITS) that take greater account of these differences in pace.

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5 See Section 11.3 of the background study in part two of this report on the American car manufacturers which are afraid that the bandwidth allocated for vehicle communication will be overloaded by nomadic devices (p. 69).

Consolidate the Netherlands as a testing country

The absence of a large national car industry also has advantages. The knowledge, test environments, and certification that are so crucial for standardisation can be developed in relatively great independence. As indicated in the Minister's memorandum to the House (16 June 2014), organisations and networks such as the RDW, DITCM and DAVI, and Dutch involvement in the international cooperative corridor can therefore be viewed as a strategic positioning within the international ITS dynamic (Parliamentary Documents II, 2013/14, 31305, No. 210). Above all, the Netherlands will need to consolidate its position as a leading country in vehicle testing. This also implies focused investment for both applied and basic research.

5.3 Big data

Various stakeholders have an interest in the data generated by smart vehicles: insurers are interested in individual behaviour and habits; marketers in the use of data on travel behaviour for personalised offers; road management authorities in applications for traffic management and planning; and finally, the data also provides an interesting new source of information for law enforcement. But amidst all these new interests, the interests of the driver – who is at the centre of the flow of data that is generated – are poorly represented. This leads to discussion about the ownership and reuse of mobility data. To stimulate innovation and prevent public controversy about the self-driving car, a clear governance framework is needed regarding the use of mobility data.

Governance of big data

The explosive growth in mobility data associated with the development of smart cars is changing the role of data in mobility, and offers all kinds of new possibilities. It also raises the question of whether the existing frameworks are adequate for directing these new kinds of use. How should the governance of mobility data be organised? That 'big data' is an important raw material for various public and private interests indicates that the general principle of 'open data' will need to be subject to numerous carefully considered exception clauses. The open character is increasingly in friction with legislation on privacy, data protection and the privacy interests of the citizen.

The discussion shows that there are limits to the reuse of data that is still seen as socially acceptable, but these limits do not always correspond with the current legal frameworks. If insufficient attention is paid to issues of privacy and data ownership, they could hamper the development of the self-driving car (Anderson et al. 2014). A clear framework regarding what is and is not permitted – taking account of the societal perspective – would provide clarity and create the necessary scope for innovation. The instrumental use of 'big data' will need to be regulated responsively and experimentally (and therefore involve regular evaluation).

5.4 Contribution by civil society

In the period ahead, cars are set to change drastically, and with them the mobility system and our mobility behaviour. Cars will become linked to other objects and to the Internet, thus creating an 'Internet of mobility'.[6] Although cautious public discussion is beginning about what uses the digital data generated by smart cars may be put to, civil-society organisations and the public currently play hardly any significant role in the development of smart and self-driving vehicles (whether that means the cooperative or the robot car). Indeed, they are conspicuously absent. Users are still not seen as inevitably involved in the social embedding of the self-driving car. The closed nature of the innovation process derives partly from conflict avoidance. Controversial issues, such as variable road pricing and privacy, are often avoided, even though the associated functionalities arise almost of their own accord. The process of strategy development in the current *Better Informed on the Road* policy programme (BGOW) was deliberately not set up too broadly because building trust between market and government was seen as a critical task.

The rate at which these changes are confronting us demands the input and involvement of users, the public, and civil-society organisations. The input of all these parties is necessary, specifically now that self-driving cars are leaving the confines of the test circuit and start driving on public roads.

6 For more information about this, see Section 12.4 of the background study in part 2 of the background study *Tem de robotauto* (Timmer & Kool, 2014).

6 Conclusion

The self-driving car is on its way, and it promises us a safer, more sustainable, and more efficient system of transport. The Netherlands is actively heading towards the self-driving car. The Ministry of Infrastructure and the Environment has announced measures, to enable this country to occupy a place among the leaders in this development. But just what kind of self-driving car are we headed for?

We have seen in this study that the one-and-only 'self-driving' car does not exist. That distinction is extremely important for thinking about the development of self-driving cars, not only in the Netherlands but also internationally. There are different lines of development: the cooperative car that is connected to the road and to other cars, and the robot car in which the technology is largely on board of the car itself. These two lines of development differ funda- mentally, both from the technological perspective and in the (collective) effects that can be achieved. The fact that cooperative systems allow for platooning means that environmental benefits and improved traffic flow can be achieved. In the case of autonomous robot cars, however, achieving these policy goals is not among the obvious possibilities. The cooperative systems can be made more effective, however, by using the smart technology of robot cars.

For the Netherlands and Europe, the robot car is a disruptive innovation. Dutch policy focuses strongly on traffic management and cooperative systems because of the favourable contribution these can make to achieving various policy objectives, for example more efficient road use, and safer and more sustainable traffic. Recently, however, there has been increased attention for the innovation path of robot cars, and the Netherlands is looking to California as a model for technology development and legislation that promotes innovation.

There is a growing awareness that the cooperative and autonomous systems will need to complement one another in order to create a viable self-driving car, i.e. one that is sufficiently reliable and cost-efficient. But this convergence will not occur naturally. As the Dutch case shows, it demands constant coordination and alignment, involving a lot of different interests. Both vehicle manufacturers and road management authorities may choose to pursue their own course, for example because they believe that doing so will give them more control over their own innovation processes. If governments and road managers continue to develop traffic management solitarily , the major boost in effectiveness provided by intelligent vehicle technology will largely fail to materialise. Likewise, if vehicle manufacturers bring relatively autonomous robot cars onto the market, the potential synergy with policy goals such as environmental benefits and improved traffic flow will be limited.

Envisaging the necessary convergence, the recent focus on the robot car in

Dutch cooperative policy can be considered positive. In Dutch policy, it is not sufficiently clear however that the two approaches – cooperative and autonomous – are fundamentally different, both technologically and with respect to what (collective) effects can be achieved, for example improved traffic flow and environmental benefits.

If the Netherlands wishes to benefit from previous (public-private) investment and the opportunities for its own industry and achieve multiple of policy goals, then it is necessary to:

1. consolidate policy towards cooperative systems;

2. embed autonomous robot vehicles in the cooperative communication structure, for example by imposing conditions for vehicle communication, so that robot cars become 'connected' cars.

The explosive growth in mobility data associated with the development of smart and self-driving cars is changing the role of data in mobility, and offers all kinds of new possibilities. It also raises the question of whether the existing frameworks are adequate for directing these new kinds of use. Discussion shows that there are limits to the reuse of data that is still seen as socially acceptable, but that these limits do not always correspond with the current legal frameworks. If insufficient attention is paid to them, they can hamper the development of the self-driving car. A clear framework regarding what is and is not permitted – taking account of the societal perspective – would provide clarity and create the necessary scope for innovation.

In the period ahead, cars are set to change drastically, and with them the mobility system and our mobility behaviour. Civil-society organisations and the public currently play hardly any significant role in the development of the smart car. The rate at which these changes are confronting us demands, however, that they be involved.

6.1 Recommendations

1. Make a distinction in policy between the two innovation paths for the self-driving car: the cooperative innovation track and that of the robot car.

2. Consolidate the focus of Dutch policy on cooperative systems. This requires:
   a. constant management and joint strategy development s to achieve and consolidate the required public-private partnership for cooperative cars;
   b. consolidation of the Netherlands as a leading testing country; in her memorandum to the House of Representatives (16 June 2014), the Minister of Infrastructure and the Environment set out the necessary steps for this, for example development of legislation that promotes

innovation so as to allow tests of cooperative cars;

c. creating optimal investment conditions: develop liability frameworks so that innovations that increase safety do not remain on the shelf unnecessarily; consider tax measures to promote the sale of cooperative cars with a view to the expected contribution to policy objectives.

3. Prevent the disruptive innovation track of the robot car from hampering the creation of cooperative systems. This means:
   a. clarity in policy as to the course to be pursued; prevent confusion about the two innovation paths among private parties and politicians;
   b. embedding of the robot car in the cooperative communication structure, for example by imposing mandatory conditions for vehicle communication; this will require constant efforts by the Netherlands within global standardisation processes, in which it should safeguard the interests of its own automotive supply industry, the traffic sector, and nomadic device industry.

4. Create a clear agenda for digitisation issues: data-driven mobility and the socially responsible innovations that arise from it are only possible if answers are found to questions regarding privacy, data protection, re-use, ownership and management of data.

5. Guarantee the contribution by the public and by civil society organisations in the innovation process. Their involvement is indispensable for the social embedding of the self-driving car.

As this study has shown, the Netherlands is facing a challenge in embedding the development of the self-driving robot car in the existing policy focusing on cooperative systems. But combining these two innovation paths is a challenge not only for the Netherlands; it is also a matter for discussion at European level. The Dutch case shows that the development of cooperative driving requires a focused process of joint strategy development and careful organisation of public-private partnerships. In our view, the issues raised here also demand answers at European level. The same applies to the discussions that are commencing in the field of investment conditions, digitisation issues, and public involvement in the innovation process. The insights generated by this study can therefore provide inspiration not only for discussion of policy in the Netherlands but also in Europe.

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Who was Rathenau?

The Rathenau Instituut is named after Professor G.W. Rathenau (1911-1989), who was successively professor of experimental physics at the University of Amsterdam, director of the Philips Physics Laboratory in Eindhoven, and a member of the Scientific Advisory Council on Government Policy. He achieved national fame as chairman of the commission formed in 1978 to investigate the societal implications of micro-electronics. One of the commission's recommendations was that there should be ongoing and systematic monitoring of the societal significance of all technological advances. Rathenau's activities led to the foundation of the Netherlands Organization for Technology Assessment (NOTA) in 1986. On 2 June 1994, this organization was renamed 'the Rathenau Instituut'.

The self-driving car is on its way, but just what do we mean by 'self-driving'? Are we talking about autonomous robot cars or cooperative cars?

The Dutch government has been promoting cooperative cars for several years. Because they can drive in platoons, they are expected to contribute to road safety as well as reducing congestion and environmental pollution. Recently, robot cars have become more important in Dutch policymaking. But because platooning is not possible with robot cars, their contribution to reducing congestion and cleaner mobility is limited.

This study aims to clarify the different innovation approaches of the self-driving car. It shows that the two approaches – cooperative systems and autonomous robot cars - raise different governance issues and social questions. To benefit from previous investments and achieve Dutch policy goals, the Netherlands should aim for convergence, and integrate the robot car with the existing approach towards cooperative systems. On the one hand, that requires robot cars that fit in with the cooperative communication structure. On the other, it means that cooperative systems should be made more effective by using the smart technology of robot cars.

ISBN 978-90-77364-65-9